Relationship Between Changes in Upon-Waking Urinary Indices of Hydration Status and Body Mass in Adolescent Singaporean Athletes

Chin Han Lew, Gary Slater, Gobinathan Nair, and Michelle Miller

This study investigated the relationship between changes in upon-waking body mass (BM) and changes in urine specific gravity ($U_{sg}$) and urine color ($U_{col}$) from 1 day to the next. Throughout the 5-day investigation, healthy adolescent Singaporean athletes ($n = 66$) had their upon-waking, bladder-voided BM measured. A small aliquot of the first bladder void each day was collected and analyzed for $U_{sg}$ and $U_{col}$, the latter by both an investigator ($IU_{col}$) and individual participants ($SU_{col}$). Results revealed a significant inverse relationship between changes in BM and changes in $U_{sg}$ ($p = .003$) and $U_{col}$ ($p = .001$). On average, $U_{sg}$ and $U_{col}$ changed by ~0.003 units and ~1 color (across a 9-unit scale), respectively, with every 1% change in BM from 1 day to the next. There was a stronger relationship between $U_{sg}$ and $IU_{col}$ ($r = .82$, $p < .001$) than between $U_{sg}$ and $SU_{col}$ ($r = .60$, $p < .001$). These results suggest that the degree of fluid deficit may be predicted from the $U_{sg}$ measurements among moderately hypohydrated athletes. In addition, training athletes to interpret and use the $U_{col}$ chart is recommended.

Keywords: urine specific gravity, urine color, hypohydration, euhydration, rehydration

Staying well hydrated is an important objective for adolescent athletes because they are at greater risk for heat illness than adults (Committee on Sports Medicine and Fitness, 2005), and even 1% body-mass loss is enough to induce a reduction in aerobic performance in thermally stressful conditions (Wilk, Yuxiu, & Bar-Or, 2002). Given the health and performance implications of hypohydration (Sawka et al., 2007), regular assessment of hydration status has become commonplace among adolescent athletes (Committee on Sports Medicine and Fitness, 2005). In the field setting, urinalysis and body-mass changes from one day to the next are often used to determine upon-waking hydration status of athletes (Sawka et al., 2007). Ideally, these indices of hydration status should provide both qualitative and quantitative information so that hypohydrated athletes can be rehydrated according to their degree of fluid deficit.

For those who are in energy balance, random variation in body mass from one day to the next will be within the range of ±1% (Cheuvront, Carter, Montain, & Sawka, 2004; Dore, Weiner, Wheeler, & El-Neil, 1975; Grandjean, Reimers, Bannick, & Haven, 2000; Grandjean, Reimers, Haven, & Curtis, 2003). A recent investigation established that 3 consecutive days of upon-waking nude (or seminude) body-mass measurements can be used to establish baseline (euhydrated) body mass in subjects adhering to fluid-replacement guidelines (Cheuvront et al., 2004). Although more than a 1% decrease in euhydrated body mass from one day to the next has been suggested to indicate hypohydration, this method of hydration assessment has limitations; namely, daily variation in body mass should not be used for periods longer than 15 days (Cheuvront et al., 2004) because chronic energy imbalance may cause body-mass changes, independent of hydration status (Buchholz & Schoeller, 2004). In addition, this technique may not be applicable in females because menstrual-cycle phase can influence fluid regulatory hormones, total body water, and thus presumably body mass (Bunt, Lohman, & Boileau, 1989). Most important, it is difficult to identify a euhydrated mass independent of another index of hydration status. Therefore, body mass is often used in conjunction with other hydration markers such as urine specific gravity ($U_{sg}$) to verify an individual’s euhydrated body mass (Sawka et al., 2007).

An upon-waking $U_{sg}$ value of ≤1.020 and/or urine color ($U_{col}$) of ≤3 has been used to indicate a state of euhydration (Casa, Clarkson, & Roberts, 2005). However, these urinary indices only provide a qualitative index of hydration status, so it is difficult to implement effective rehydration strategies without being able to quantify any existing fluid deficit. In view of this, a recent study systematically correlated $U_{sg}$ with hydration status, but
no relationship could be established because of the large interindividual variation of U$_{\text{sg}}$ measurements at baseline (Bartok, Schoeller, Sullivan, Clark, & Landry, 2004). Although other studies (Oppliger, Magnes, Popowski, & Gisolfi, 2005; Popowski et al., 2001) that included progressive acute dehydration protocols have found U$_{\text{sg}}$ to increase by -0.004 units with every 1% dehydration, it is not clear whether this relationship persists in the hours postexercise.

Urine color is a more assessable tool for routine monitoring of hydration status in an athlete population. A validated U$_{\text{col}}$ chart was developed by Armstrong et al. (1994) and has been commonly used in subsequent studies (Armstrong et al., 1998; Kovacs, Senden, & Brouns, 1999). All U$_{\text{col}}$ analyses in these studies were analyzed by the investigator rather than the athlete. In the local setting, athletes often analyze their U$_{\text{col}}$ using an unvalidated U$_{\text{col}}$ chart produced by the Gatorade company because of its availability. Hence, the applicability of U$_{\text{col}}$ as a hydration indicator in the practical setting remains to be addressed.

The aim of this study was to investigate the relationship between changes in upon-waking urinary indices of hydration status (U$_{\text{sg}}$ and U$_{\text{col}}$) and body-mass changes from one day to the next. We hypothesized that there would be an inverse relationship between changes in upon-waking body mass and urinary indices of hydration status. If this association could be assessed, it would enable the degree of fluid deficit in hypohydrated individuals to be quantified, allowing a more prescriptive rehydration strategy to be implemented. A secondary aim of this study was to investigate the applicability of U$_{\text{col}}$ analyses performed by the athletes (SU$_{\text{col}}$). We hypothesized that there would be a strong relationship between U$_{\text{sg}}$ and U$_{\text{col}}$ independent of whether color was assessed by an investigator (IU$_{\text{col}}$) or athlete.

Methods

Participants

Male and female athletes from the soccer, netball, swimming, and track and field academies of the Singapore Sports School were invited to participate in this investigation. All participants and their parents were fully informed of the nature of the investigation before the parents provided written informed consent. Participants with previously diagnosed cardiovascular disease, renal disease, endocrine disorders, or color blindness were excluded from the study. The investigation was approved by the Flinders Medical Centre Clinical Research and Ethics Committee and given executive approval by the Singapore Sports School.

Experimental Procedures

In accordance with the fasting and weighing protocols of Cheuvront et al. (2004), the investigation was carried out over 5 consecutive weekday mornings when athletes were residing in sport school lodging. Throughout the investigation, participants were instructed to consume food and fluid ad libitum. In addition, physical activity was not standardized to ensure a wider variability in hydration status so we could investigate the relationship between percent body-mass changes and the urinary indices of hydration in both directions. Participants were also instructed to fast overnight (no food or fluid in the 8 hr before sampling) and refrain from ingesting any dietary supplements. An upon-waking, overnight-fasted first bladder void (midstream) was collected into a transparent inert polypropylene container each morning. Thereafter, participants went to the laboratory and completed a 1-page questionnaire that sought information on compliance to the study protocol. Additional questions were included to monitor the menstrual-cycle phase of female participants, because this has been shown to influence body mass (Bunt et al., 1989). Participants were also instructed to assess their U$_{\text{col}}$ by comparing their container of urine with the Gatorade U$_{\text{col}}$ chart against a designated white wall in a well-lit area. The color interpretations printed on the U$_{\text{col}}$ chart were concealed to minimize their influence on the participants’ U$_{\text{col}}$ interpretation. To enhance the precision of measurement on the linear yellow color gradient on the Gatorade U$_{\text{col}}$ chart, the chart was divided into nine equal segments (originally separated into three) with each segment numbered in ascending order starting from the lightest shade to the darkest (i.e., 1–9). As such, Colors 1–3 were in the left side of the color bar (lightest colors and interpreted as well hydrated) of the original chart, 4–6 were in the middle of the color bar (dehydrated), and 7–9 were in the right side of the bar (darkest colors and interpreted as severely dehydrated). The colors in the U$_{\text{col}}$ chart were matched with the following Process Color (CMYK) combinations (cyan, magenta, yellow, key): Color 1: Y = 35; Color 2: Y = 45; Color 3: Y = 55; Color 4: Y = 65; Color 5: M = 10, Y = 60, K = 10; Color 6: M = 10, Y = 65, K = 20; Color 7: M = 10, Y = 70, K = 30; Color 8: M = 20, Y = 85, K = 30; Color 9: M = 20, Y = 90, K = 40 (Rogondino & Rogondino, 2000).

On completing the questionnaire and U$_{\text{col}}$ analysis, each participant was weighed in minimal clothing (identical throughout the study) on a digital scale (±0.1 kg; SECA 780, Germany) that was calibrated before the study began and assessed for drift each day of the investigation using 40- and 60-kg weights. All body-mass measures were undertaken in duplicate, with the mean used in subsequent statistical analyses. In our laboratory, this technique has a typical error of 0.1% (Hopkins, 2000).

Urine Analyses

The presence of glucose and protein, confounders of U$_{\text{sg}}$ measures (Voinescu, Showmaker, Moore, Khanna, & Nolph, 2002), as well as blood, a confounder of U$_{\text{col}}$ measurement (Raymond & Yarger, 1988), was assessed using urine reagent strips (LaTech Diagnostic, URT-5K, Wilmington, DE, USA). Urine samples with results exceeding the minimum detectable amount for glucose and protein (5.5 mmol/L and 0.3 g/L, respectively) and
any color changes in the blood reagent segment of the strip were excluded from any further urinary analysis.

$U_{\text{sg}}$ was measured using a calibrated digital refractometer ($\pm 0.001$; Atago, UG-1, Tokyo, Japan), with the mean of duplicate measures used in subsequent analyses. This technique has a typical error of $<0.1\%$ in our laboratory. $IU_{\text{col}}$ was assessed daily by the same investigator in the same location where the assessments were undertaken by participants. This measurement technique has a typical error of $11.7\%$ (equates to $\pm 1$ $U_{\text{col}}$ across the 9-unit scale).

### Data Calculations

Percent body-mass changes from one day to the next, present body mass – body mass of previous day)/(body mass of previous day $\times 100$), and change in $U_{\text{sg}}$, $IU_{\text{col}}$, and $SU_{\text{col}}$ from one day to the next, present $U_{\text{sg}}$ or $IU_{\text{col}}$ or $SU_{\text{col}}$ – $U_{\text{sg}}$ or $IU_{\text{col}}$ or $SU_{\text{col}}$ of previous day, were calculated for each participant. Percent coefficient of variation in body mass for each participant (SD for mean daily body mass [kg]/mean daily body mass [kg] $\times 100$) and a grand mean, as well as a pooled standard deviation, were calculated to characterize the body-mass data of participants.

### Statistical Analyses

Normality of the data was verified using the Shapiro-Wilk test. Independent $t$ tests were used to compare characteristics between genders. A nested analysis of variance (ANOVA) was used to determine the relationship between body-mass changes and $U_{\text{sg}}$, as well as $U_{\text{col}}$, from one day to the next. Pearson’s product–moment correlation analysis was performed to determine the relationship between $U_{\text{sg}}$ and $SU_{\text{col}}$, $U_{\text{sg}}$ and $IU_{\text{col}}$, and $SU_{\text{col}}$ and $IU_{\text{col}}$. All data are presented as $M \pm SD$ unless otherwise specified. Statistical analysis was undertaken using the Statistical Package for Social Sciences (version 11.5 for Windows, SPPS Inc., Chicago, IL). Statistical significance was set at $p < .05$.

### Results

A total of 140 athletes volunteered for this investigation, yielding a response rate of 92%. Three male participants were excluded from the study because of color blindness, and 3 male participants withdrew before the study began because of lower limb injuries. Therefore, a total of 134 eligible participants were recruited, yielding the possibility of having 536 data points in all, given that each participant would provide 4 data points for investigation (Mon–Tues, Tues–Wed, Wed–Thurs, and Thurs–Fri). As documented in the questionnaire, 19 participants were menstruating and 49 participants acknowledged consuming food or fluid on waking or consuming dietary supplements (e.g., multivitamins, vitamin B complex, creatine, or guarana) on 1 or more days of the investigation. Body-mass and urinary data of noncompliant and menstruating participants were excluded from statistical analysis. Hence, data from 66 participants (264 data points) were analyzed. Data from all participants (compliant and noncompliant: 13 provided 3 data points, 27 provided 2 data points, and 9 provided 1 data point) were also analyzed. The data points of participants on the specific days of noncompliance were excluded, and these missing data were managed with the nested ANOVA. Descriptive data on the volunteers are reported in Table 1. All variables were normally distributed.

### Table 1 Descriptive Characteristics for Participants

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compliant, $n = 36$</td>
<td>All, $n = 66$</td>
</tr>
<tr>
<td>Age (years)</td>
<td>15.0 ± 0.9 (14–16)</td>
<td>15.0 ± 0.8 (14–16)</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>54.5 ± 8.9 (33.0–75.8)</td>
<td>55.0 ± 8.8 (33.0–75.8)</td>
</tr>
<tr>
<td>Body mass % CV</td>
<td>0.87 ± 0.27* (–1.84 to 2.58)</td>
<td>0.89 ± 0.45* (–1.84 to 2.58)</td>
</tr>
<tr>
<td>Training (hr/day)</td>
<td>3.2 ± 0.4 (2.4–3.6)</td>
<td>3.2 ± 0.4 (2.4–3.6)</td>
</tr>
<tr>
<td>$U_{\text{sg}}$</td>
<td>1.021 ± 0.007 (1.010–1.037)</td>
<td>1.021 ± 0.006 (1.006–1.037)</td>
</tr>
<tr>
<td>$IU_{\text{col}}$</td>
<td>5.1 ± 1.8 (1–9)</td>
<td>5.2 ± 1.9 (1–9)</td>
</tr>
<tr>
<td>$SU_{\text{col}}$</td>
<td>4.7 ± 1.6 (1–9)</td>
<td>4.8 ± 1.7 (1–9)</td>
</tr>
</tbody>
</table>

*Note: Values are $M \pm SD$ with the range of absolute values in parentheses. Compliant indicates those who provided all 4 data points. CV = coefficient of variation; $U_{\text{sg}}$ = urine specific gravity averaged over all days; $IU_{\text{col}}$ = urine color analyzed by an investigator averaged over all days; $SU_{\text{col}}$ = urine color analyzed by participants averaged over all days.

*Significant difference between males and females ($p = .001$).
All urine analyses were carried out in a 16 °C air-conditioned environment and completed within 3.5 ± 0.3 hr of collection. Because most of the female volunteers (68.1%) had difficulties recalling the first day of their previous menses, stage of ovulation was not considered in the statistical analysis.

**Relationship Between Changes in Body Mass and Urinary Indices of Hydration Status**

There was a significant inverse relationship between changes in body mass and variation in U<sub>sg</sub> and IU<sub>col</sub> from one day to the next, and the magnitude of the relationship is similar for participants who provided all 4 data points and the total group of participants (Table 2). This inverse relationship also existed between daily variance in body mass and SU<sub>col</sub> values, but the effect was generally not significant (Table 2).

**Relationship Between Urinary Indices of Hydration Status**

There was a strong correlation between U<sub>sg</sub> and IU<sub>col</sub> (r = .82, p < .001, n = 134), as indicated by the line of regression in Figure 1. However, the relationships between U<sub>sg</sub> and SU<sub>col</sub> (r = .60, p < .001, n = 134) and between IU<sub>col</sub> and SU<sub>col</sub> (r = .60, p < .001, n = 134) were not as strong. A U<sub>sg</sub> of 1.020 (common euhydration cutoff value) equated to a U<sub>col</sub> of 5 (midpoint of the color bar) on the Gatorade U<sub>col</sub> chart.

**Discussion**

To our knowledge, this is the first study to systematically investigate the relationship between changes in upon-waking body mass and urinary indices of hydration status from one day to the next. In agreement with our primary hypothesis, a significant inverse relationship was identified between changes in upon-waking body mass and urinary indices of hydration status. U<sub>sg</sub> and U<sub>col</sub> changed by ~0.003 units and ~1 color, respectively, for every 1% change in body mass.

Our findings are similar to those of Oppliger et al. (2005) and Popowski et al. (2001) despite those investigations having assessed the relationship between indices of hydration status and progressive acute dehydration protocols over approximately 3 hr compared with the current investigation, in which daily comparisons were made. In these acute investigations, U<sub>sg</sub> values increased

**Table 2 Inverse-Regression Coefficients of Urine Specific Gravity and Urine Color for Every 1% Change in Upon-Waking Body Mass**

<table>
<thead>
<tr>
<th></th>
<th>U&lt;sub&gt;sg&lt;/sub&gt;</th>
<th>p</th>
<th>IU&lt;sub&gt;col&lt;/sub&gt;</th>
<th>p</th>
<th>SU&lt;sub&gt;col&lt;/sub&gt;</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>compliant, n = 36</td>
<td>0.002 ± 0.001</td>
<td>.003</td>
<td>0.7 ± 0.2</td>
<td>.006</td>
<td>0.1 ± 0.2</td>
<td>.685</td>
</tr>
<tr>
<td>compliant and &gt;1% body-mass change</td>
<td>0.002 ± 0.001</td>
<td>.146</td>
<td>0.8 ± 0.4</td>
<td>.070</td>
<td>0.2 ± 0.4</td>
<td>.512</td>
</tr>
<tr>
<td>all, n = 66</td>
<td>0.002 ± 0.001</td>
<td>.002</td>
<td>0.7 ± 0.2</td>
<td>.001</td>
<td>0.0 ± 0.2</td>
<td>.851</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>compliant, n = 30</td>
<td>0.003 ± 0.001</td>
<td>.045</td>
<td>0.7 ± 0.2</td>
<td>.009</td>
<td>0.6 ± 0.3</td>
<td>.075</td>
</tr>
<tr>
<td>compliant and &gt;1% body-mass change</td>
<td>0.004 ± 0.002</td>
<td>.130</td>
<td>1.0 ± 0.3</td>
<td>.040</td>
<td>1.2 ± 0.6</td>
<td>.091</td>
</tr>
<tr>
<td>all, n = 68</td>
<td>0.003 ± 0.001</td>
<td>.003</td>
<td>0.7 ± 0.3</td>
<td>.006</td>
<td>0.7 ± 0.2</td>
<td>.001</td>
</tr>
<tr>
<td>Both genders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>compliant, n = 66</td>
<td>0.003 ± 0.001</td>
<td>.003</td>
<td>0.7 ± 0.2</td>
<td>.001</td>
<td>0.2 ± 0.2</td>
<td>.237</td>
</tr>
<tr>
<td>compliant and &gt;1% body-mass change</td>
<td>0.003 ± 0.001</td>
<td>.026</td>
<td>0.9 ± 0.3</td>
<td>.012</td>
<td>0.1 ± 0.3</td>
<td>.701</td>
</tr>
<tr>
<td>all, N = 134</td>
<td>0.003 ± 0.001</td>
<td>&lt;.001</td>
<td>0.7 ± 0.2</td>
<td>&lt;.001</td>
<td>0.3 ± 0.1</td>
<td>.018</td>
</tr>
</tbody>
</table>

*Note.* Values are M ± SE. Compliant indicates those who provided all 4 data points. U<sub>sg</sub> = urine specific gravity; IU<sub>col</sub> = urine color analyzed by an investigator; SU<sub>col</sub> = urine color analyzed by participants.
by ~0.004 units with every 1% decrease in body mass induced via exercise in warm environments (Oppliger et al., 2005; Popowski et al., 2001). Although the average change in $U_{sg}$ in the current investigation was similar, results of Oppliger et al. and Popowski et al. suggested that the increase in $U_{sg}$ became proportionally smaller with larger fluid deficits (i.e., 5% of body mass). This suggests that at high levels of dehydration, there is little capacity for further concentration of urine (Kavouras, 2002). Consequently, our results may not apply when substantial fluid losses have occurred given that the maximum body-mass loss in our study was 2.37% (Table 1). This issue warrants further investigation.

Recognizing that body-mass changes remain the most realistic surrogate to changes in hydration status in the field setting (Maughan, Shirreffs, & Leiper, 2007), upon-waking changes in body mass from one day to the next were used as a surrogate for changes in total body water. Although we recognize that substrate oxidation, metabolic water, water stored with glycogen, and urine and fecal water losses have been proposed to affect the use of body-mass changes as a surrogate for effective body-water loss during prolonged exercise (Maughan et al., 2007), their effects on body-mass changes from one day to the next as a surrogate to changes in total-body water remain unclear. Previous research using the isotope-dilution technique has confirmed that changes in total-body water and upon-waking body mass from one day to the next generally move in the same direction and magnitude (Bartoli, Davis, Pate, Ward, & Watson, 1993). In addition, gastrointestinal contents are unlikely to significantly influence upon-waking body mass because they are a diurnal constant (Cheuvront et al., 2004).

Quantifying the relationship between changes in upon-waking body mass and urinary indices of hydration status from one day to the next offers the possibility to predict the degree of fluid deficit in moderately hypohydrated athletes using urinary indices of hydration status. However, given the high typical error of $U_{sg}$ analysis, only $U_{sg}$ should be used for this purpose. Hence, with reference to an upon-waking $U_{sg}$ of 1.020 as euhydration (Bartok et al., 2004; Oppliger et al., 2005; Popowski et al., 2001), measurements of upon-waking $U_{sg}$ of 1.023 and 1.026 would indicate 1% and 2% fluid deficits, respectively (Table 2). Conversely, the hydration status indicated by measurements of upon-waking $U_{sg}$ of 1.017 and 1.014 would be 1% and 2%, respectively, above euhydration. It is also important to note that recent food and fluid ingestion have been shown to violate the accuracy of urinary (Casa et al., 2005) and body-mass measurements (Broad, Burke, Cox, Heelley, & Riley, 1996) as hydration indicators. Therefore, these factors need to be taken into consideration when estimating fluid deficit and thus fluid requirements. To ensure complete rehydration, current guidelines suggest that at least 125–150% of any fluid deficit be replaced with 50–100 mmol/L of sodium-containing fluids, acknowledging normal fluid needs and ongoing fluid losses from obligatory urine losses during the rehydration period (Casa et al., 2005).

Hence it seems prudent for a 60-kg adolescent athlete with an upon-waking $U_{sg}$ of 1.023 (equivalent to ~1%, or ~600-ml fluid deficit) to consume at least 750 ml of sodium-containing fluid (125% of existing fluid deficit) to effectively rehydrate.

Our results do not agree with the National Athletic Trainers’ Association position statement regarding fluid replacement (Casa et al., 2000). For example, they classified athletes presenting with a $U_{sg}$ value of 1.023 to be in ~3% fluid deficit, whereas our results indicate a 1% fluid deficit (using a $U_{sg}$ cutoff of ≤1.020). This is most likely because of differences in euhydration cutoff values between investigations (Bartok et al., 2004; Oppliger et al., 2005; Popowski et al., 2001).

Data from previous investigations have shown that $U_{sg}$ measurements are likely to be more sensitive to fluid deficits in excess of 1% of body-mass loss (Grandjean et al., 2000; Grandjean et al., 2003). As such, we anticipated that the association between changes in upon-waking body mass and urinary indices of hydration status would not be as strong for participants hypohydrated by within ±1% of body mass. However, this was not supported by our results. A possible explanation for this may be that most participants who were deemed to have less than a 1% change in body mass may have already been in a hypohydrated state given that the average upon-waking $U_{sg}$ was 1.021. Hence, it appears that the resolution necessary to detect the change in hydration status among participants who had ±1% change in body mass.

Given that the Gatorade $U_{col}$ chart has not been previously validated, we carried out a method of validation similar to that adopted by Armstrong et al. (1994) in our study. Similar to the works of Armstrong et al. (1994, 1998), who found a strong relationship between $U_{sg}$ and $I U_{col}$ ($r = 0.80–0.99, p < .001$), we also found a strong relationship between these indices of hydration status using the Gatorade $U_{col}$ chart. The relationship between $U_{sg}$ and $SU_{col}$ was not as strong because of interindividual variability in $U_{sg}$ perception (evident by the moderate relationship between $IU_{col}$ and $SU_{col}$). These results indicate that the $U_{col}$ interpretation of adolescent athletes may not be as accurate as those of an investigator. Hence, training adolescent athletes to interpret $U_{col}$ should be considered because the Gatorade $U_{col}$ chart provides qualitative indication of hydration status that will empower the athletes with the ability to assess their own hydration status.

**Conclusion**

In summary, the current investigation showed an inverse relationship between changes in upon-waking body mass and urinary indices of hydration status from one day to the next. For every 1% change in body mass, $U_{sg}$ and $SU_{col}$ changed by ~0.003 units and ~1 color (across a 9-unit scale), respectively. Given the high typical error of $U_{col}$ analysis, the use of $U_{sg}$ measurements offers the possibility of providing moderately hypohydrated athletes a more prescriptive rehydration protocol. In addition, training on the interpretation and use of the commercially available
Gatorade $U_{\text{col}}$ chart should be provided for adolescent athletes if this assessment tool is to be used in practice.

Acknowledgments

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